Operative Techniques in Thoracic and Cardiovascular Surgery

Segmental Approach to Repair of Regurgitant Bicuspid Aortic Valves

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The bicuspid design for the aortic valve is less optimal than the tricuspid one. Nevertheless, more than 1% of the population has a bicuspid aortic valve (BAV), and the majority of these valves serve the owners well for life.[1,2] Important regurgitation has been reported to occur in 15 to 20% of patients with BAV, most often presenting clinically in young and middle-aged adults.[3]

The observed natural history indicates the potential for durability of good BAVs and justifies repair of regurgitant BAVs. A follow-up study from our institution[4] comparing freedom from reoperation after aortic valve repair (predominantly of BAVs), autograft root replacement, allograft root replacement, and bovine prosthesis replacement confirmed that repair is a competitive option with a lower risk of reoperation beyond 10 years than any of the replacement alternatives. Although association with dilation of the aorta is no longer a matter of debate,[5] valve repair associated or not with reduction aortoplasty or aortic replacement, depending on the degree of aortic dilation, may be of benefit for a significant proportion of patients with BAVs.[6-9]

Initially, the bicuspid valve design seems simple and easy to understand and repair. Only a single coaptation line has to be successfully realigned for BAVs, in contrast to the more complex interface of three coaptation lines of tricuspid valves. In our recent study of BAV repairability, 57% of regurgitant BAVs were successfully repaired and echocardiography features predicting repairability were defined.

Bicuspid valve repair has evolved in our institution over the last two decades.[9-12] A detailed, logical, and segmental approach to morphology and repair should improve intraoperative decision making and refine the choices of repair techniques and maneuvers, resulting in better repairs of a higher percentage of patients with regurgitant BAVs. Segmental approach stands for cusps, commissures, and root. Repair maneuvers should be pathology-specific. The decision-making process is based on thorough preoperative evaluation using computer tomography and transthoracic echocardiography and is further complemented by intraoperative transesophageal echocardiography and finally by direct surgical inspection and analysis.

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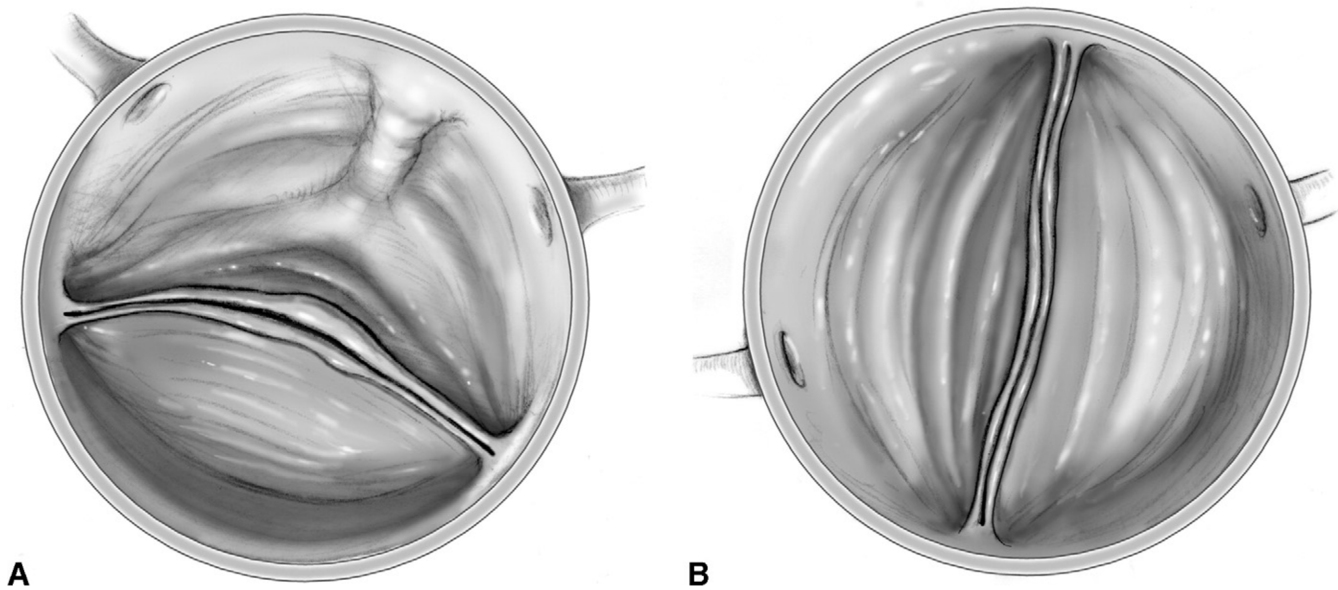


Figure 1 The leading repair principle is to transform the valve into the best possible bicommissural/bicuspid valve given the morphology and pathologic changes of the valve and root. A typical good bicuspid valve (A) is competent, displays complete fusion of the conjoint cusp, and has a raphe. The valve presents with one normal-looking cusp, called by us the reference cusp, and one larger cusp, appearing to be the result of fusion of two cusps normally encountered in the tricuspid form of aortic valve (conjoint cusp). Right and left cusp fusion remains most common, and the conjoint cusp is usually larger than the reference cusp; the ratio between the two cusps can be anywhere between 1:1 and 2:1. If the fusion is complete and the two cusps are coapting properly, one has a good functioning valve without regurgitation. In systole, it opens with a "fish-mouth" appearance; although the valve area is large, there is always some turbulence and a low gradient. This valve may remain well functioning for life or it may eventually thicken, calcify, and become stenotic, requiring surgery later in life. BAVs exhibiting two symmetrical cusps with horizontal orientation and no raphe are less common (B).

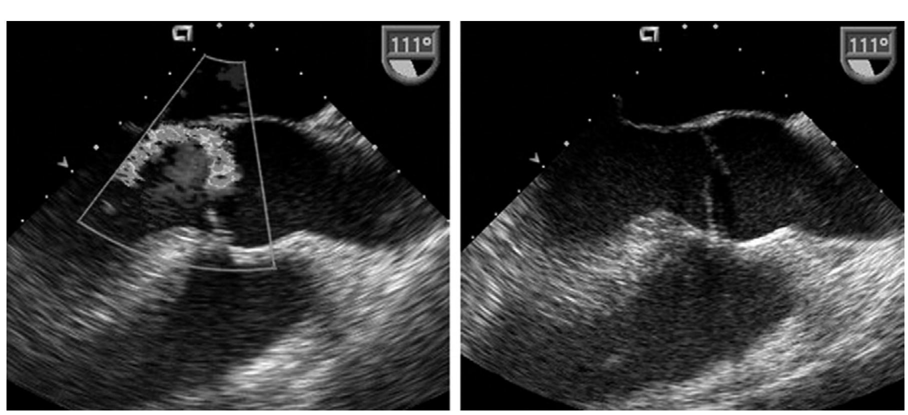


Figure 2 The morphology-directed repair begins with careful review of the intraoperative transesophageal echocardiogram (TEE). The following are reviewed: severity of regurgitation; number and direction of regurgitant jets; possible mechanism(s) of regurgitation; valve morphology segment by segment; cusps, commissures, and root. Two echocardiographic long-axis-view images selected from a patient with a BAV demonstrate two main features suggesting repairability: thin, mobile, noncalcified cusps (prolapse of the anterior fused cusp as seen in the right-handed image) and a very eccentric jet (directed posteriorly on the left-handed image).

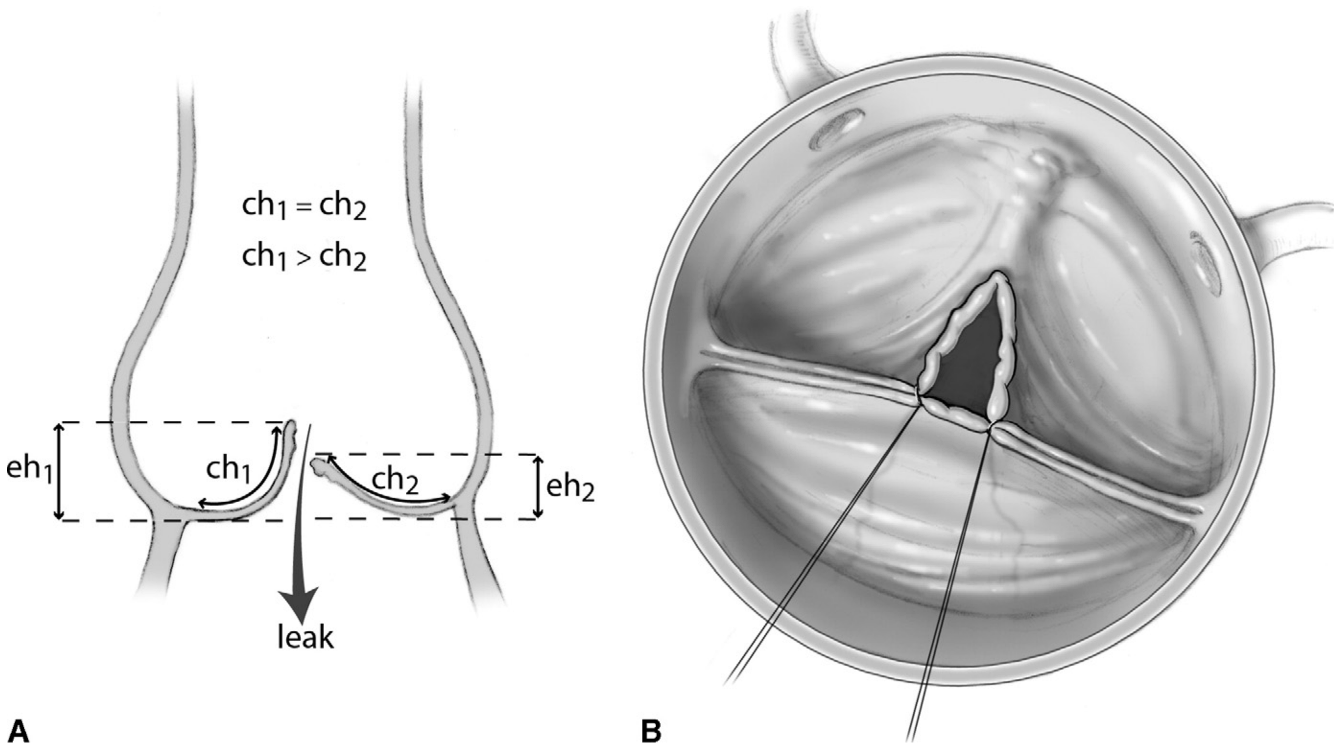


Figure 3 Aortic valve repair is performed via mini or full sternotomy using direct aortic and atrial cannulation, cardiopulmonary bypass, and cardioplegia. A transverse aortotomy is standard. The surgical observations and readings of the valve morphology segment by segment (cusps, commissures, and root geometry) are systematically evaluated. The quality parameters of the cusps are size and shape, integrity, and mobility determined by thickness and calcification. A key observation is identification of the regurgitant orifice (or orifices), delineated by cusp free margin thickening. Repairable valves have one normal cusp, the reference cusp, and a conjoint cusp with sufficient cusp tissue to transform it into a good matching second cusp. Any pathologic condition of the reference cusp has to be easily repairable, eg, a perforation. The reference cusp should have a normal relationship between the base (attachment to the aortic wall) and its free margin, a good or normal "effective height." Compare the cusp height (ch), which is equal for the two cusps, with the effective height (eh), which differs, allowing for regurgitation.[13] Effective height is an easy way to understand and measure the relative prolapse of the cusp (A). Next, the conjoint cusp is examined in detail; this is facilitated by lining up the free margins of the good portions of the conjoint cusp against the free margin of the reference cusp starting at each commissure. Fine stay-sutures are placed to support the lineup (B). This lineup will often produce a "cleft" in the conjoint cusp corresponding with the incomplete fusion and the raphe. Invariably the cleft will delineate the regurgitant orifice and display thickening of the free margins. Cusp tissue availability is determined to be excessive, adequate, or deficient (see also Figs. 5, 6, and 7).

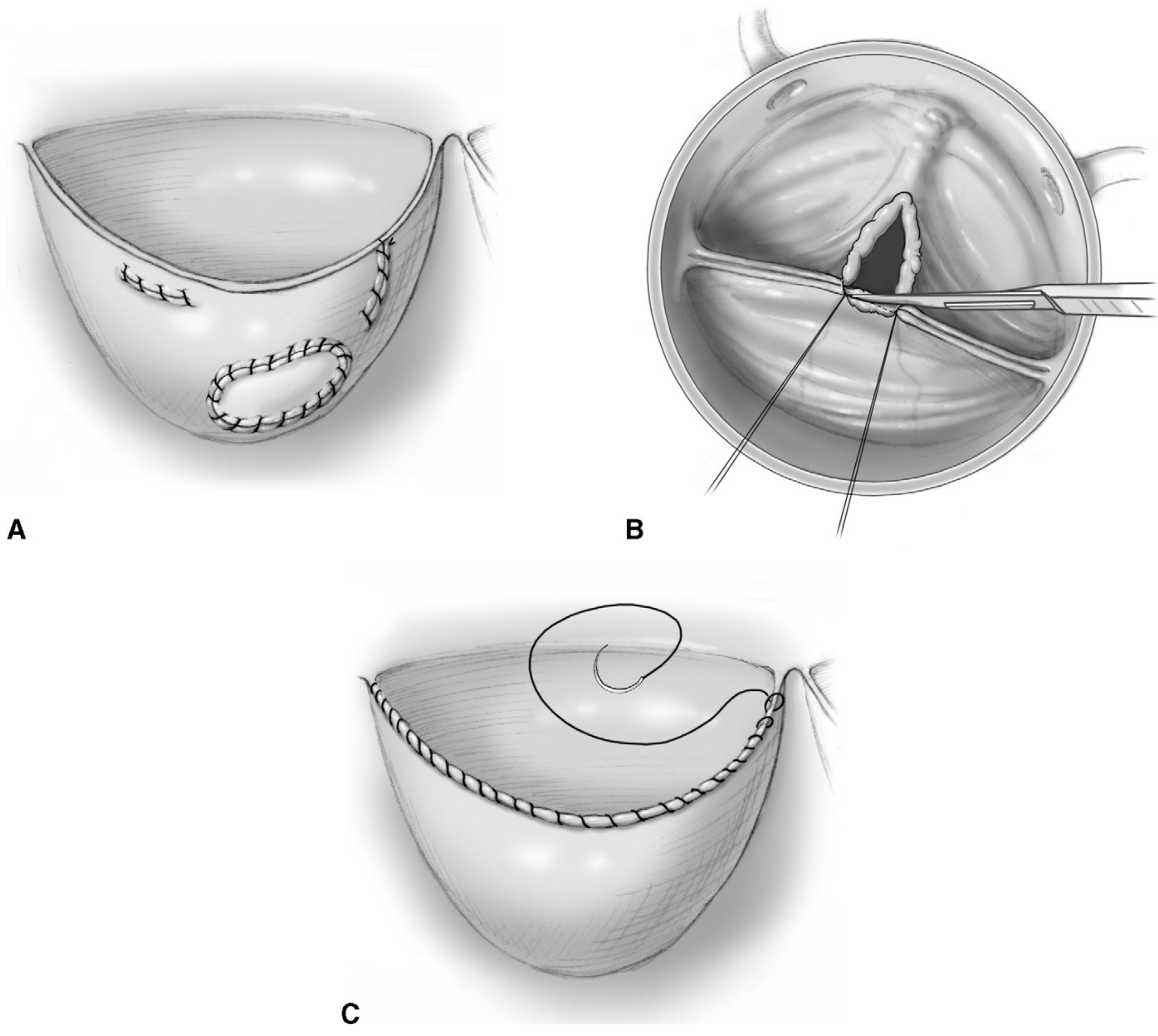


Figure 4 Cusp integrity (A). Lack of cusp integrity, fenestrations, tears, and perforations are identified. Fenestrations only occasionally need to be repaired. Perforations in the belly are repaired with fresh autologous pericardium. The margins are usually thick enough for safe suturing. Tears and minimal perforations are directly sutured. Sutures in a normal thin portion of a cusp have a high risk of tearing; iatrogenic injuries in these areas should be avoided. For these cusp repairs, 7-0 monofilament or 5-0 braided sutures are used. Shaving/debridement (B). The repair of the cusps may continue with cautious shaving of excessive thickening of the free margins when justified. Some residual free-margin thickening is left to allow safe suturing. Free margin reinforcement (C). Free margin reinforcement is seldom indicated. It may be considered for the reference cusp if the free margin is stretched (reduced effective height) and very thin. A 7-0 polypropylene suture is run over and over the free margin from commissure to commissure with short throws, making sure the cusp is not shortened more than desired.

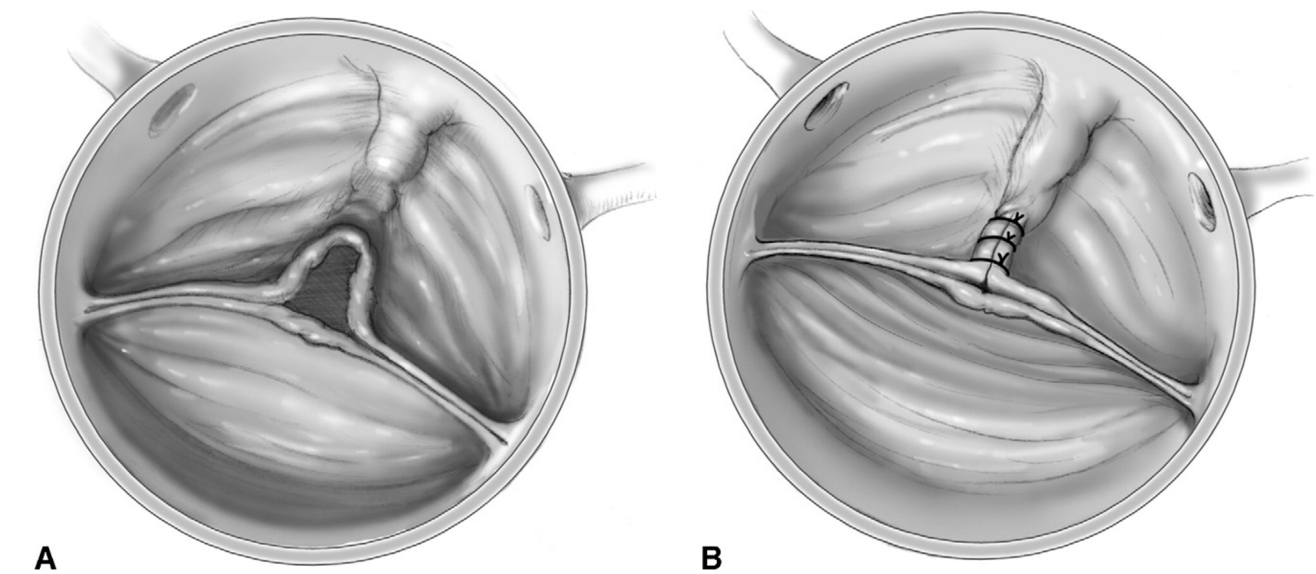


Figure 5 "Cleft" conjoint cusp with sufficient or excess tissue/size (A). The most important and deciding step of the repair is to equalize the length of the free margins of the two cusps. Most often, the two portions of the conjoint cusp have enough cusp tissue to make up for a second good cusp after completed bicuspidalization (B) by direct closure of the "cleft" with interrupted stitches. (We still refer to this kind of repair as plication, although it does not involve excess tissue.)

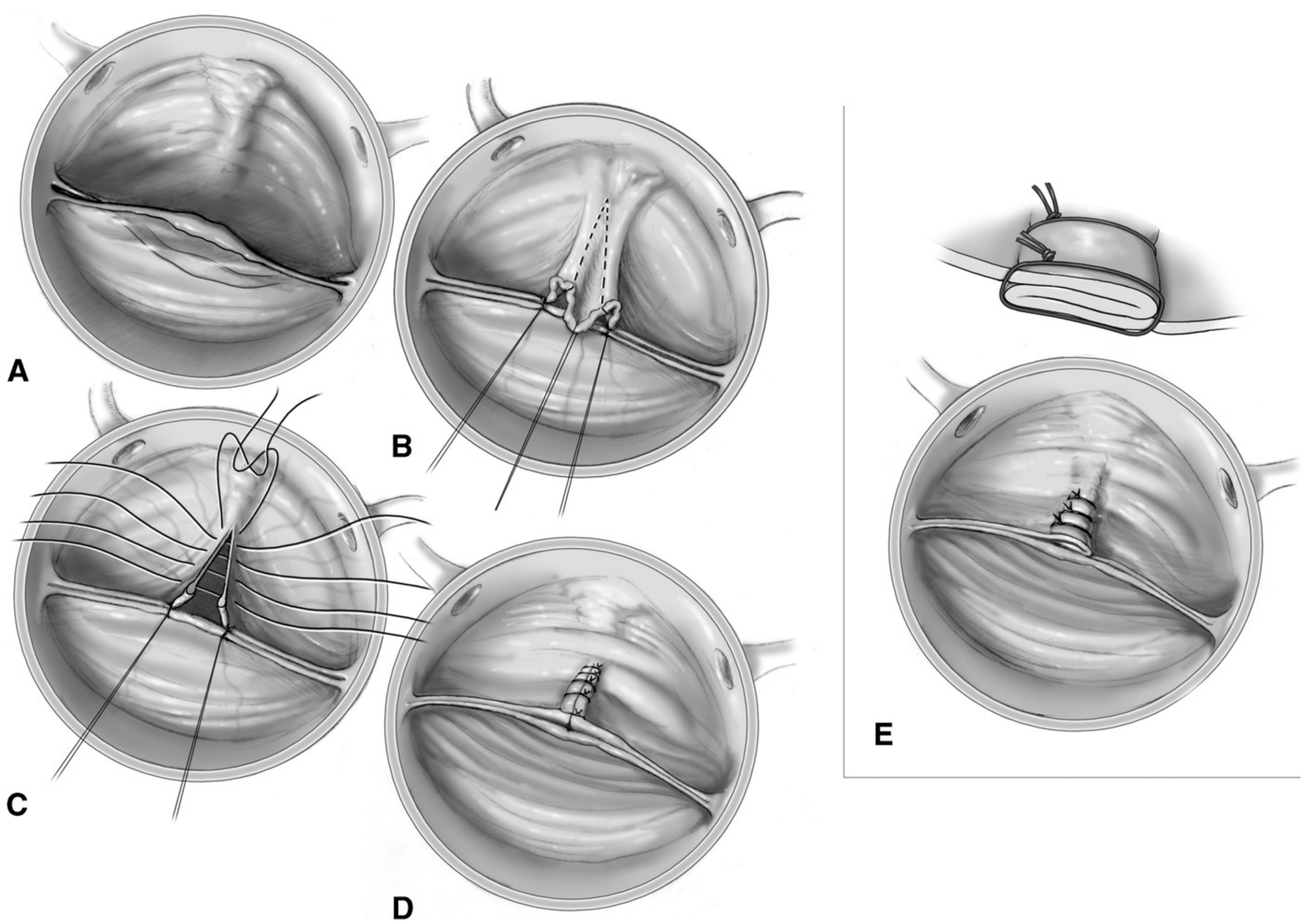


Figure 6 Complete fusion of the conjoint cusp with excess tissue/size and prolapse (A). In the case of true excessive cusp tissue, the choice is between plication and triangular resection. Our choice has been triangular resection when the prolapsing cusp has a significant amount of excessive tissue (B) and good quality margins left for safe suturing (C, D). True plication may be attractive when the cusp is thin and the excessive tissue is less impressive (E). Nevertheless, the correction, whether it is triangular resection or plication, should equalize the lengths of the two cusps (D, E).

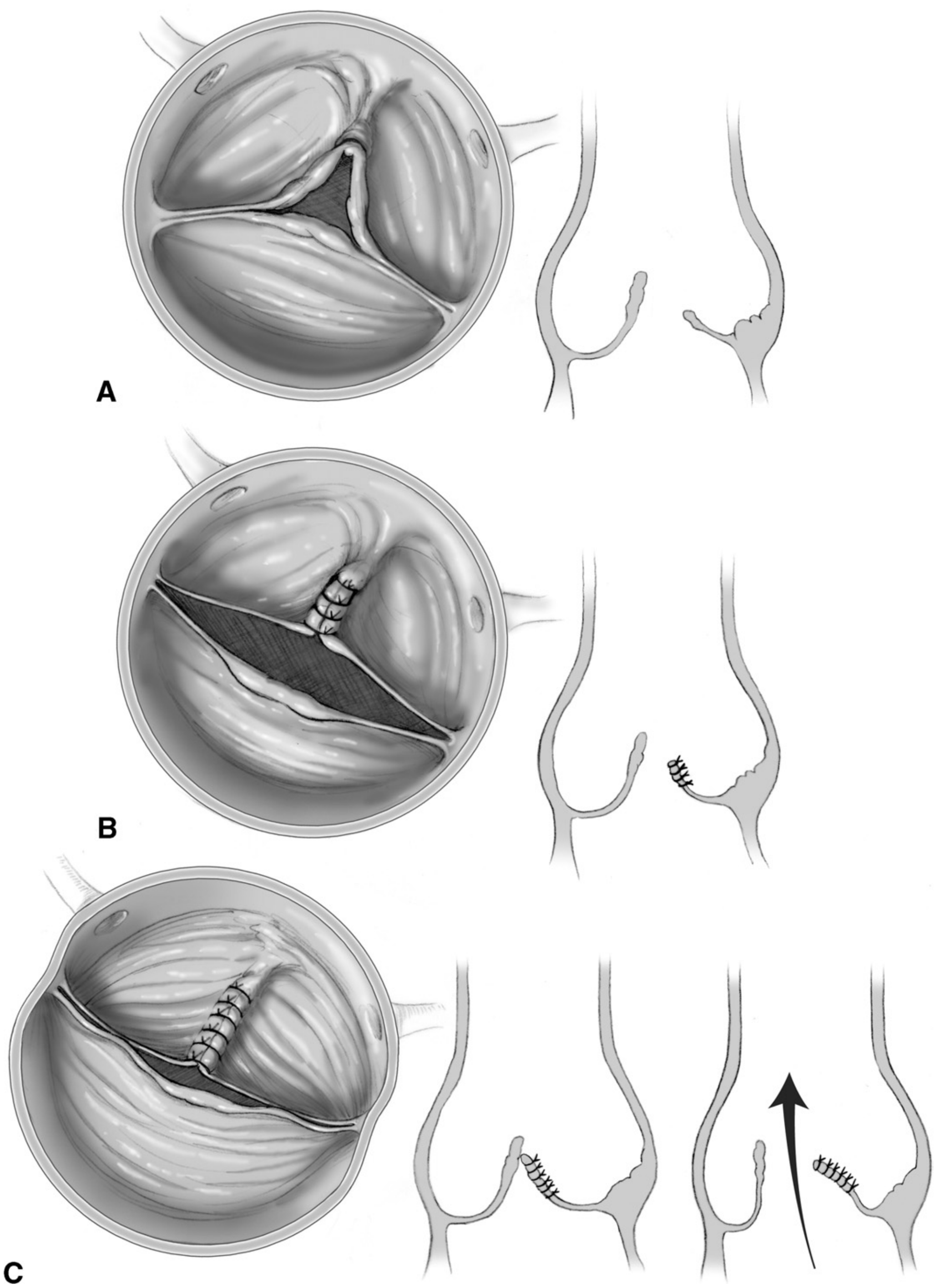


Figure 7 Cusp tissue deficiency/restriction. The main issue that remains is what to do in the case of tissue deficiency and restriction. Tissue deficiency or restriction may become apparent at any stage during the repair and may be the main reason for us not to repair or to abort a repair attempt (A, also in longitudinal or long axis view). Overcorrection is considered when echocardiography demonstrates residual central regurgitation after correction, equalizing the free margins of the two cusps (B). Overcorrection of the conjoint cusp is performed during a second pump run and means making the free margin of the conjoint cusp shorter than the reference cusp (C, with two longitudinal views of the valve coapting in diastole and doming in systole). Overcorrection improves coaptation at the expense of increased systolic doming and a higher gradient but may still be acceptable in a young patient with a large, perfectly opening reference cusp, allowing a large valve area. With overcorrection, the valve area is decided entirely by the reference cusp. We have not used cusp augmentation with pericardium, as suggested by others. Other maneuvers to compensate for restrictions such as anulus reduction by plication or resection and release of the raphe have not been effective. At present, the raphe is usually left alone.

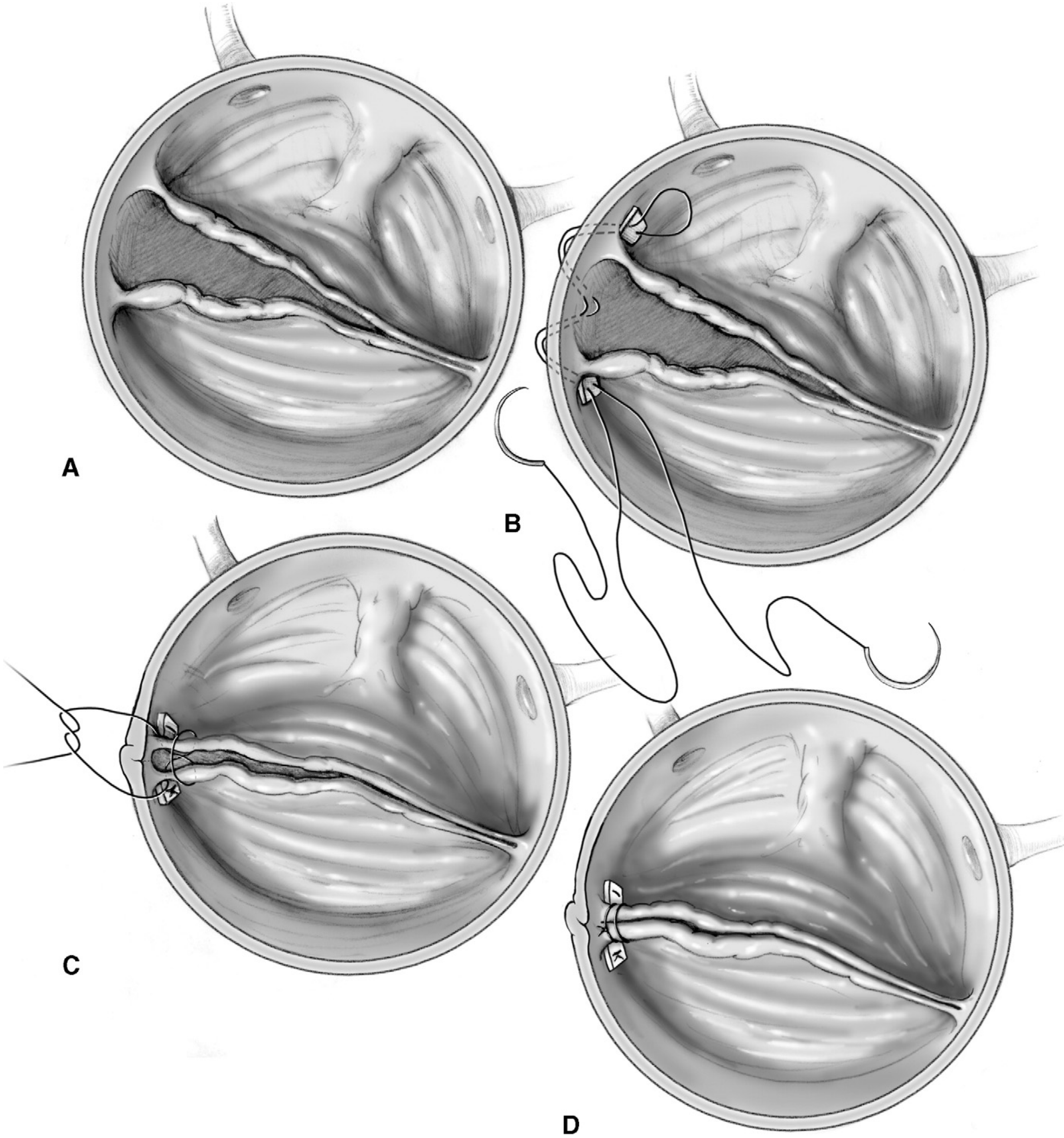


Figure 8 The following repairable commissural pathologies are encountered: splaying, malalignment in height (always associated with some degree of splaying), and detachment (appearing similar to a locally contained dissection). Splaying to a degree resulting in a commissural jet, a "drop jet" identified by echocardiography, is uncommon but can still occasionally be impressive. Important splaying or malalignment is addressed by a pledgeted suture (a Cabrol-like stitch)[14] to realign and bring the commissure together (the stitch is horizontal in B and oblique in E). These pledgeted sutures are always supported with a commissuroplasty type figure-of-eight suture at the free margin close to the commissure to prevent residual splaying (C and F). A figure-of-eight suture alone takes care of minor splaying but, in the absence of cusp-free margin thickening and any commissural jet on echocardiography, it may be unnecessary.

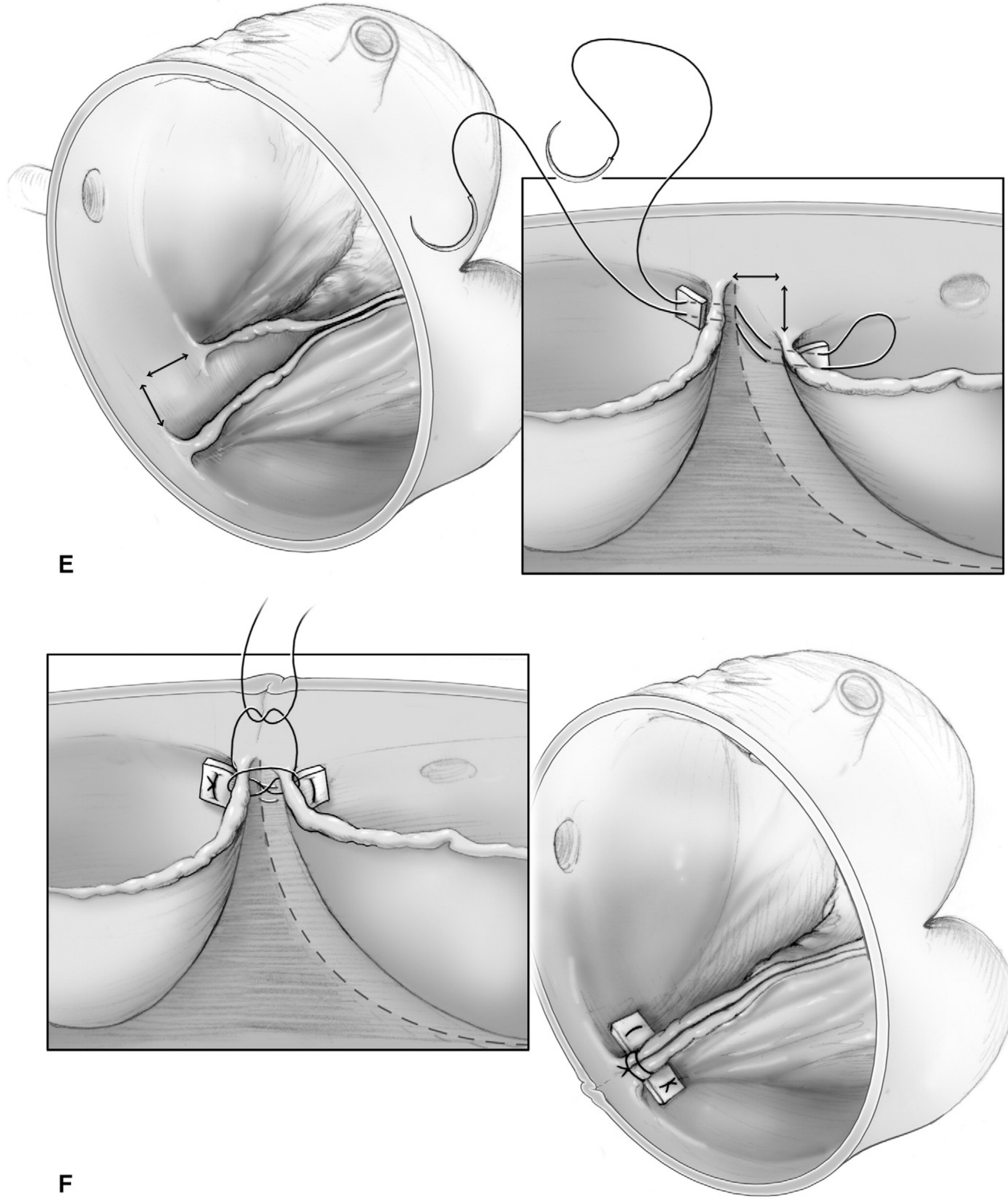


Figure 8 (Continued)

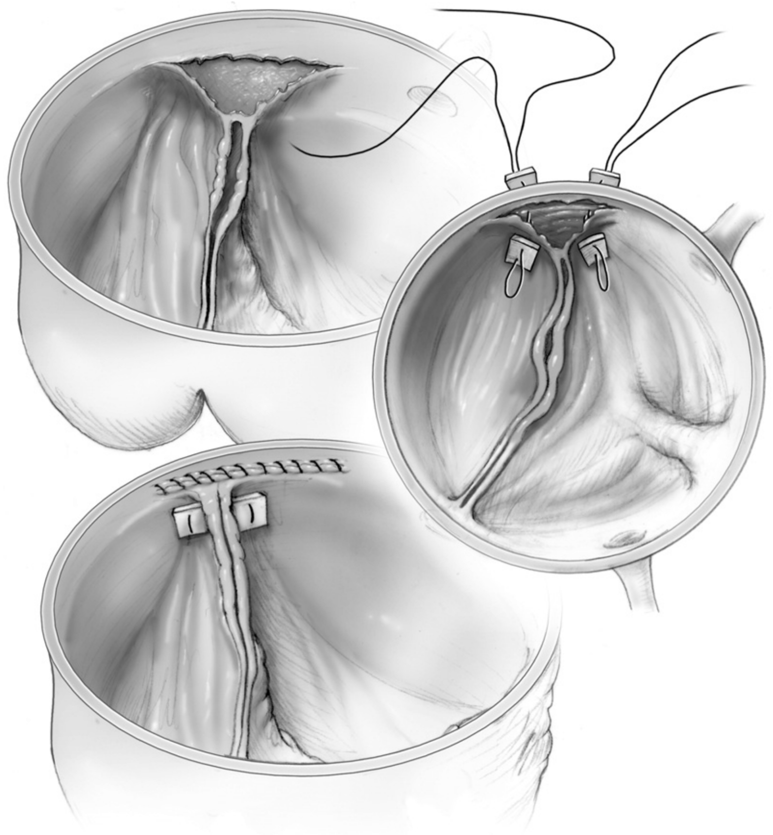
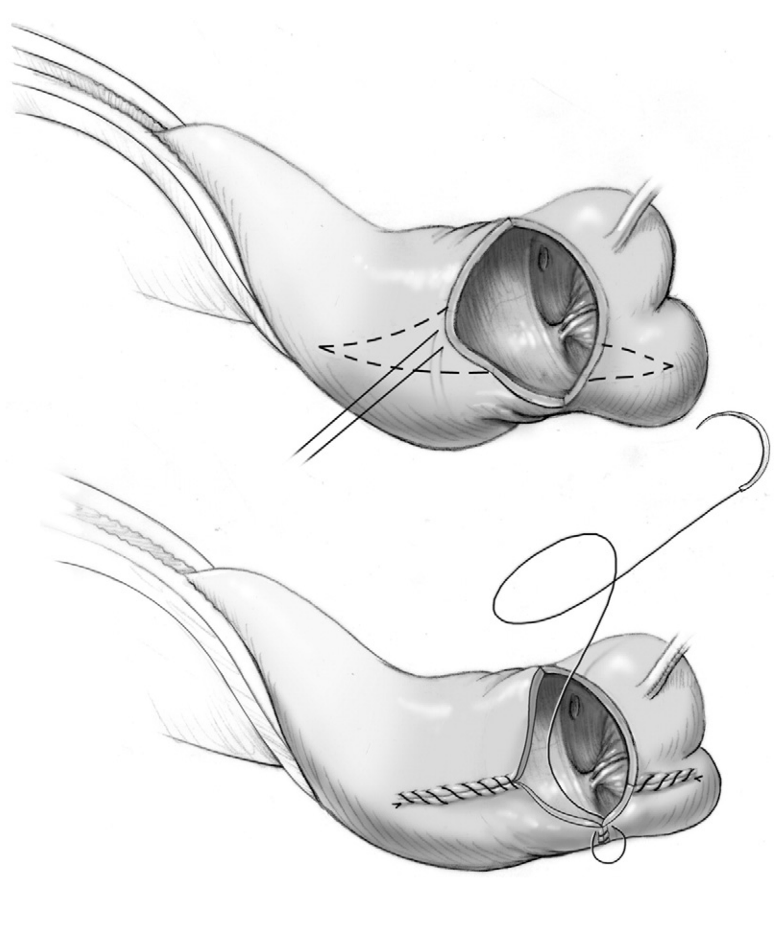


Figure 9 A detached commissure, mimicking a locally contained dissection, is resuspended with one pledgeted suture on either side of the commissure and a running horizontal suture to plicate the aortic wall corresponding to the detachment. Commissural issues are usually obvious and easy to repair.

Figure 10 Aortic reduction or replacement. Preoperatively, all patients undergo aortic computed tomography (CT) scans to determine the dimensions of the aortic root, ascending aorta, and aortic arch. The need for aortic replacement or reduction aortoplasty is primarily determined by this examination and by taking into consideration the patient's size, age, and tissue quality. A dilation at the sinus of Valsalva level to more than 4.5 cm and at the sinotubular junction above 4 cm is usually addressed. Dilation of the root and sinuses beyond the above-mentioned numbers has been observed in about one-third of our patients with BAV regurgitation; in these cases we have performed valve repair as described, combined with reduction aortoplasty or supracoronary ascending aorta replacement. For mild dilation, <4.5 cm, and good aortic wall quality, a longitudinal reduction aortoplasty reducing the diameter of the aorta to about 3 to 3.5 cm is performed.

When in doubt about tissue quality, tube graft replacement is preferred. The diameter of the graft is determined by the length of the free margin of the reference cusp minus 3 to 5 mm; a smaller graft may cause cusp prolapse. If the diameter of the distal ascending aorta exceeds 3 to 3.5 cm, hemiarch replacement in deep hypothermia and circulatory arrest is warranted. Remodeling has only been performed with good bicuspid valves not requiring any cusp or commissural repair procedures. In the case of asymmetric dilation of the noncoronary (reference cusp) sinus, reduction aortoplasty and single tongue remodeling have been used.



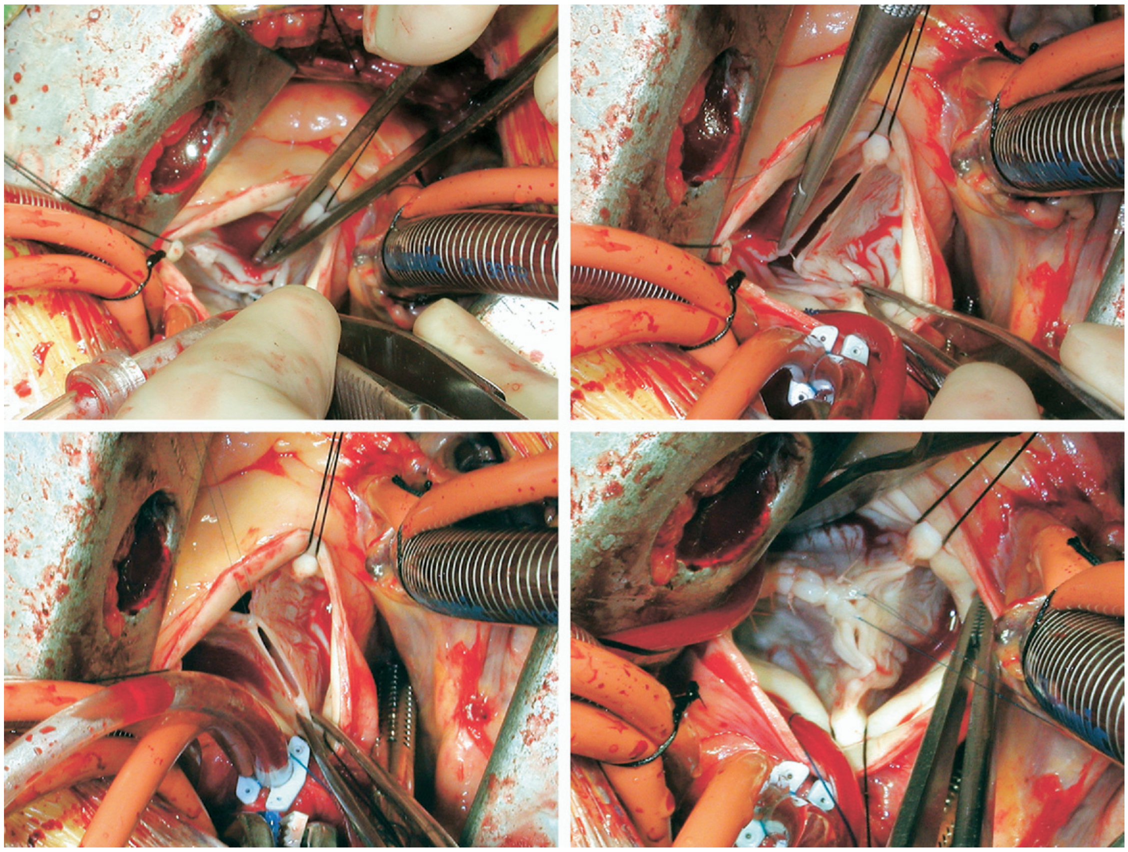


Figure 11 Intraoperative photos of BAV repair: cusp analysis after exposure (upper right image), cusps lined up, and direct suture (plication, completed bicuspidalization) of the "cleft" (regurgitant orifice) with interrupted braided 5-0 sutures. (Color version of figure is available online at http://www.us.elsevierhealth.com/optechstcvs.)

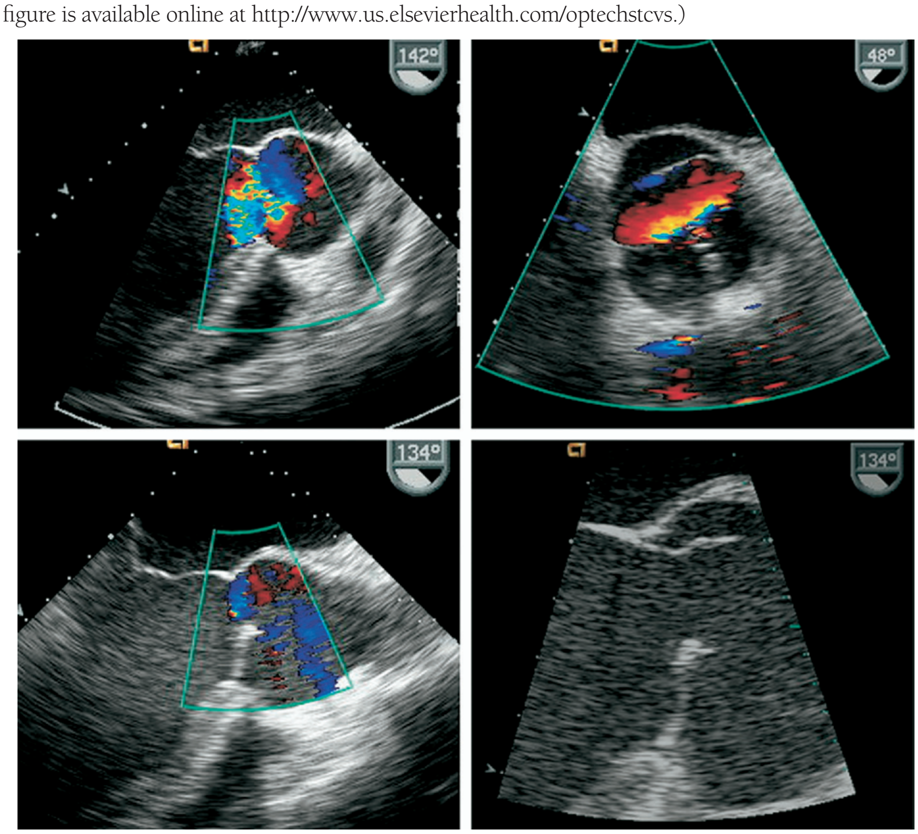


Figure 12 Echocardiographic images of the same valve before (left upper image showing severe regurgitation in longitudinal view) and after repair. Left lower image shows no residual regurgitation in diastolic longitudinal view, and the remaining images demonstrate restricted systolic opening and doming of the conjoint cusp in short- and long-axis views. The peak and mean gradients across the valve in systole were 14 and 7 mm Hg, respectively. The postrepair restricted opening and doming are related to the repaired conjoint cusp being larger than the reference cusp. When doming occurs, the valve area is decided by the reference cusp being normal and opening fully. (Color version of figure is available online at http://www.us.elsevierhealth.com/optechstcvs.)

Conclusions

Presently, more than two-thirds of all regurgitant bicuspid valves requiring intervention are successfully repaired at our institution. Present criteria for acceptable repair are residual regurgitation <1+ and peak and mean gradients of <30 and <15 mm Hg, respectively. The 10-year reoperation rate is <20%, half of the failures occurring within the first year. The described segmental- and pathology-directed approach is another attempt to make aortic valve repairs more reproducible. Repair maneuvers being pathology-specific should also improve our understanding of the correlation between morphology/pathology and function. Three-dimensional (3D) echocardiography and gated CT scanning are imaging techniques that we expect to play an increasingly important role in the near future for patient selection and further development of our repair techniques. Not only the durability of valve repairs but also the rate and frequency of continuing aortic root dilation and development of aneurysm and/or dissection will decide the future applicability of bicuspid aortic valve repair.

Acknowledgments

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